PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 12(1): 1-7
https://doi.org/10.14719/pst.5937

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RESEARCH ARTICLE

Impact of drip fertigation on nutrient use efficiency, dynamics, water productivity and bulb yield in Aggregatum onion

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OPEN ACCESS

ARTICLE HISTORY
Received: 22 November 2024
Accepted: 20 December 2024
Available online
Version 1.0 : 29 December 2024
Version 2.0 : 01 January 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

CITE THIS ARTICLE
Natarajan SK, Sampathkumar T, Bhuvaneswari J, Manikandan M, Thenmozhi S. Impact of drip fertigation on nutrient use efficiency, dynamics, water productivity and bulb yield in Aggregatum onion. Plant Science Today. 2025; 12(1): 1-11. https://doi.org/10.14719/pst.5937

Abstract

A field experiment was conducted on aggregatum onion (*Allium cepa* L. var. *aggregatum* Don.) under a drip irrigation system to evaluate the water productivity, nutrient use efficiency, nutrient dynamics and yield of onion in order to optimize the best fertigation level. The experiment was designed in a Randomized Block Design (RBD), with treatments replicated 3 times. The treatment details are as follows: T_1- 100% nitrogen (N) through fertigation with100% phosphorus (P) and potassium (K) applied as basal; T_2- 100 % N and K through venturi as fertigation and basal application of 100 % P; T_3- 100% N, P and K through fertigation; T_4- 75% N, P and K through fertigation with basal application of 25% N, P and K; T_5- 75% N through fertigation with 75% P and K applied as basal; T_6- 75% N and K through venturi as fertigation with basal application of 75% P; T_7- 75% N, P and K through fertigation; T_8- 75% of N, P and K through fertigation and 25% of 75% N, P and K applied as basal; T_9- 50% N 100% P and K applied as basal and 50% N applied on 30 DAT; T_{10}- absolute control (no fertilizer). The results indicated that the bulb yield of aggregatum onion was significantly higher in 100% N, P and K through fertigation (23.24 to 23.47 t ha^{-1}). Among the different fertigation treatments, the 100% N, P and K through fertigation recorded higher water use efficiency (75.08 to 78.44 kg/ha mm), water productivity (7.841 to 7.508 kg m^{-3}) and nutrient use efficiency, which was comparable to the 75% N, P and K through fertigation.

Keywords

Aggregatum onion; drip fertigation; nutrient use efficiency; water use efficiency; nutrient dynamics

Introduction

Small aggregatum onion (*Allium cepa* L. var. *aggregatum* Don) is a popular vegetable in south India and produced commercially in Tamil Nadu. Tamil Nadu is one of the major onion producing states with production of 3.01 lakhs tonnes in an area of 0.28 lakhs ha. Small onion occupies nearly 75% of the total onion produced in India with a productivity of 12 t ha^{-1} (1). However, productivity remains low in India, mainly due to lack of scientific management of irrigation water and nutrients which determined the yield of the crop. Its production is rapidly increasing under irrigated conditions. The area under onion cultivation in the country is increasing every year, mainly due to its high profitability. However, the average yield is low due to insufficient information on proper fertilizer and irrigation schedules and lack of appropriate technology. This can be improved through the use of micro-irrigation systems, which increase water and nutrient use efficiency compared to conventional irrigation system.

In India, the average productivity of aggregatum onion is about 16.41 t ha^{-1}, which is lower than world's average of 20.08 t ha^{-1} which needs crop production strategies to increase the productivity of the crop (1). One of the reasons for this low productivity is the surface irrigation method predominantly adopted by farmers, which results in low productivity. Onion, a shallow-rooted crop, requires frequent irrigation, but surface irrigation methods result in low water use efficiency. By adopting a drip irrigation system, high water use efficiency and better productivity can be achieved by maintaining moisture near the root zone at field capacity. Drip irrigation resulted in water savings of up to 39%, with 520 mm of water applied compared to 840 mm for surface irrigation (2). The field water use efficiency of drip irrigation was 2.5 times higher when compared to conventional methods. Given the limited research on onion cultivation using drip fertigation, this study aims to optimize drip fertigation techniques to improve both water and nutrient use efficiency, ultimately boosting onion yields.

Materials and Methods

An on-farm research experiment was conducted on aggregatum onion (*Allium cepa* L. var. *aggregatum* Don.) under a drip irrigation system to study the growth, yield and economics of onion cultivation under different fertigation treatments and to optimize the best fertigation level. The study was carried out at the Agriculture Research Station, Bhavanisagar, during 2017-2018 and 2018-2019 growing seasons. The experimental field's soil was sandy clay loam in texture. Soil samples were collected at a depth of 15 cm prior to the experiment and analyzed for various physico- chemical characteristics. The results indicated that the soil was low in available nitrogen (N) (250 kg ha^{-1}), high in available phosphorus (P) (24 kg ha^{-1}) and medium in available potassium (K) (352 kg ha^{-1}). The on-farm research experiment was laid out in a Randomized Block Design (RBD) with 3 replications and a plot size of 22.5 m × 0.9 m.

T_1	100% N through venturi with100% basal application of P and K
T_2	100% N and K through venturi with100% basal application of P
T_3	100% N, P and K through fertigation
T_4	75% N, P and K through fertigation and basal application of 25% N, P and K
T_5	75% N through fertigation with75% P and K applied as basal
T_6	75% N and K through venturi as fertigation and basal application of 75% P
T_7	75% N, P and K through fertigation
T_8	75% of 75% N, P and K through fertigation and 25% of 75% N, P and K applied as basal
T_9	50% N 100% P and K applied as basal and 50% N applied on 30 DAT
T_{10}	Absolute control (No fertilizer)

The treatment details are as follows.

Irrigation water was pumped using a 7.5 HP motor and water was conveyed to the main line, made up of PVC pipes with 63 mm OD (outer diameter), after filtering through sand and disc filters. A venturi system was installed in the mainline for fertigation. Sub-mains, constructed with PVC pipes of 40 mm OD, were connected to the main pipes. Lateral lines made of 12 mm LDPE pipes were spaced at 1.2 m intervals, with inline emitters positioned 50 cm apart, discharging at a rate of 4 L/h. Individual control valves were installed for each treatment to facilitate different fertigation applications. A single lateral line was used for each bed, which contained 4 rows of onion crops. The wetting diameter of a single dripper was 0.5 m. The sub-mains and laterals pipes were sealed with end caps. After installation, a test run was conducted to measure the mean dripper discharge and irrigation efficiency. Based on the observations, irrigation time was determined. During the cropping period, the average irrigation efficiency was recorded as approximately 90%.

Drip irrigation

The first irrigation was applied before transplanting and subsequent irrigations were scheduled on alternate days using the daily pan evaporation values. Irrigation was applied at 100 % Crop Evapotranspiration (ETc). The water requirement (WR) was calculated as follows:

$$\text{WR (mm/irrigation)} = \frac{\text{PE x Kp x Kc}}{\text{IE}} \text{ x } 100$$

$$\text{WR (L/unit area/irrigation)} = \frac{\text{PE} \times \text{Kp} \times \text{Kc} \times \text{A}}{\text{IE}} \text{ x } 100$$

where,

PE = Pan evaporation (mm)

Kp = Pan co-efficient (0.70)

Kc = Crop co-efficient

Initial stage (1-20 DAT)	0.70
Mid-season stage (21-60 DAT)	1.05
Late season stage (61-80 DAT)	0.80 (FAO, 2014)

A = Area (m2)

IE = Irrigation efficiency (90 %)

The operation time of the drip irrigation system to deliver the required quantity of irrigation water was calculated using the formula,

$$\text{Time of application (min)} = \frac{\text{Volume of required water (L/plot) x 60}}{\text{Emitter discharge (L h}^{-1}\text{) x No. of emitters/plot}}$$

Fertigation was scheduled based on the soil test crop response (STCR) based fertilizer prescription equation developed for onion in the Irugur soil series. The STCR method is a technique that helps to determine the amounts of fertilizers to specific location or similar soil in a particular agro-eco region (3).

Fertilizer Prescription Equations for onion under STCR

STCR equation for requirement of major nutrients viz., NPK

FN = 0.9 T-0.37 SN

FP2O5 = 0.58 T-1.43 SP

FK2O = 0.67 T-0.44 SK

where,

FN, FP_2O_5 and FK_2O are N, P_2O_5 and K_2O fertilizers (in kg ha^{-1}) respectively

T is the yield target in q ha^{-1}

SN, SP and SK are available soil N, P and K (in kg ha^{-1}) respectively.

The STCR approach to fertilizer application is a scientific method used to optimize crop productivity while maintaining soil health. This approach increased the crop productivity, efficient use of fertilizer and cost effective. STCR NPK approach was used for calculation of fertilizer dose by substituting initial soil test values viz., N (245), P (24) and K (350). The calculated fertilizer dose was 120**: 99:60** N, P_2O_5, K_2O, Kg ha^{-1} respectively adopted for application to crop. (** maximum dose 200% of RDF). The targeted yield of onion was fixed as 230 q ha^{-1}.

The fertilizers used for drip fertigation included urea (46% N), poly feed (19:19:19), mono ammonium phosphate (12:61:0) and sulphate of potash (50% K). For basal application, conventional fertilizers such as urea (46% N), single super phosphate (16% P) and muriate of potash (60% K) were used. The required quantities of fertilizers were dissolved in water and applied from the 2nd to the 11th week after transplanting, as per the fertigation schedule (refer to Table 1).

Table 1. Fertigation schedule as per growth stage.

Sl. No.	Crop stage	Duration (in Days)	Fertigation frequency days	% requirement		
				N	P	K
1	Vegetative stage	1-30	7	30	50	20
2	Bulb formation stage	31-60	7	40	30	50
3	Bulb development stage	61-90	7	30	20	30
	Total	**90**		**100**	**100**	**100**

Nutrient use efficiency (NUE)

NUE was calculated using the following formula and expressed as yield (kg) per kg of nutrients (N, P and K) applied per ha applied.

$$NUE = \frac{\text{Yield (kg ha}^{-1})}{\text{Nutrient applied (kg/ha)}}$$

Soil nutrient dynamics under drip irrigation

Soil samples were collected from 2 horizontal points relative to emitters (0 cm and 25 cm on both sides) and 2 vertical points (0-15 cm and 15-30 cm) below the soil surface on both sides of each lateral emitter. Soil samples were collected at 60 DAT using a screw auger for 3 treatments:

- **T3**: 100% N, P and K through fertigation.
- **T7**: 75% N, P and K through fertigation.
- **T8**: 75% NPK via fertigation and 25% as basal application.

The samples air dried, ground, sieved (2 mm) and stored in polythene bags for the estimation of nutrients viz., available N, P and K (kg ha^{-1}). The available N, P and K were mapped in both horizontal and vertical dimensions by using SURFER- version 7.0 software (developed by Golden Software of USA) which show the 3 dimensional view of soil nutrient distributions from the emitter. Surfer software was a contouring package includes 3D surface mapping program which is compatible with Microsoft Windows Operating System.

Results and Discussion

Nitrogen use efficiency

The application of different drip fertigation treatments significantly influenced NUE across both years (Table 2). The treatment with 75% N, P and K through fertigation (T_7) resulted in the highest NUE (252.7 and 254.0 kg ha^{-1}). Moderately high NUE was noticed in treatment T_8 (75% of 75% N, P and K through venturi fertigation and 25% of 75% N, P and K as basal application) (226.2 and 227.3 kg ha^{-1}) and T_6(75% N and K through venturi as fertigation with 75% P applied as basal) (213.3 and 214.4 kg ha^{-1}). Lower NUE values were recorded in treatments T_9 (50% N 100% P and K applied as basal and 50% N applied on 30 DAT 50% N 100 % P and K applied as basal and 50% N applied on 30 DAT) (147.9 and 148.6 kg kg^{-1}), T_1(100% N through fertigation with basal application of 100% P and K; 150.9 and 151.7 kg kg^{-1}) and T_2(100% N and K through fertigation with basal application of 100% P) (166.8 and 167.6 kg kg^{-1}), indicating the importance of balanced nutrient application for optimal nitrogen use and Lower NUE values were recorded in treatment of absolute control.

Phosphorus use efficiency

Phosphorus use efficiency (PUE) was also significantly influenced by the fertigation treatments in both the experiments (Table 2). The higher PUE was found in both the years with 75% N, P and K through fertigation (T_7) (307.3 and 308.8 kg kg^{-1}). PUE was moderately increased and comparable with drip fertigation of 75% of 75 % N, P and K through fertigation and 25% of basal application of 75% N, P and K applied (T_8) (275.2 and 276.6 kg kg^{-1}), 75% N and K through venturi as fertigation with basal application of 75% P (T_6) (259.4 and 260.7 kg kg^{-1}) and 100% N, P and K through fertigation (T_3) (258.3 and 259.6 kg kg^{-1}). Distinctly lower and comparable values of PUE was recorded in the treatment in which basal application of 50% N, 100% P and K and 50% N applied on 30 DAT (T_9) (179.2 and 180.1 kg kg^{-1}) and 100% N through fertigation with 100% P and K applied as basal (T_1) (182.9 and 183.8 kg kg^{-1}), barring absolute control.

Potassium use efficiency

Drip fertigation has shown significant influence on the potassium

Table 2. Nutrient use efficiency (kg kg^{-1}) of onion as influenced by drip fertigation treatments.

Treatment	First experiment			Second experiment		
	N	P	K	N	P	K
T_1- 100% N through fertigation with 100% P and K applied as basal	150.9	182.9	301.8	151.7	183.8	303.3
T_2- 100% N and K through fertigation with 100% P applied as basal	166.8	222.4	333.7	167.6	223.5	335.4
T_3- 100% N, P and K through fertigation	193.7	258.3	387.5	194.7	259.6	389.4
T_4- 75% N, P and K through fertigation and 25% N, P and K applied as basal	171.9	229.2	343.8	172.8	230.3	345.5
T_5- 75% N through fertigation with 75% P and K applied as basal	191.2	232.5	382.4	192.2	233.7	384.3
T_6- 75% N and K through fertigation with 75% P applied as basal	213.3	259.4	426.6	214.4	260.7	428.7
T_7- 75% N, P and K through fertigation	252.7	307.3	505.4	254.0	308.8	507.9
T_8- 75% of 75% N, P and K through fertigation and 25% of 75% N, P and K applied as basal	226.2	275.2	452.5	227.3	276.6	454.8
T_9- 50% N and 100% P, K applied as basal and 50% N applied on 30 DAT	147.9	179.2	295.8	148.6	180.1	297.3
SEd	**10.7**	**13.9**	**27.4**	**10.8**	**14.0**	**27.5**
CD (P=0.05)	**22.6**	**29.5**	**58.1**	**22.7**	**29.6**	**58.4**

use efficiency (KUE) (Table 2) during both the years of study. The highest KUE was noticed with 75% N, P and K through fertigation (T_7) (505.4 and 507.9 kg kg^{-1}) which was at par with 75% of 75% N, P and K through fertigation and 25% of 75% N, P and K applied as basal (T_8) (452.5 and 454. kg kg^{-1}),75% N and K through fertigation with 75% P applied as basal (T_6) (426.6 and 428.7 kg kg^{-1}), registered moderate potassium use efficiency and was at par with 75% of 75% N, P and K through fertigation with 25% of 75% N, P and K applied as basal (T_8). Substantially lower and comparable KUE was recorded in 50% N 100% P and K applied as basal and 50% N applied on 30 DAT (T_9) (295.8 and 297.3 kg kg^{-1}), 100 % N through fertigation with 100% P and K applied as basal (T_1) (301.8 and 303.3 kg kg^{-1}), 100% N and K through fertigation with 100% P applied as basal (T_2) (333.7 and 335.4 kg kg^{-1}) and 75% N, P and K through fertigation with 25% N, P and K applied as basal (T_4) (343.8 and 345.5 kg kg^{-1}). Higher nutrient use efficiencies in treatments like T_3 (100% N, P and K through fertigation) were attributed to enhanced nutrient uptake due to minimized leaching losses and efficient root zone utilization. This corroborate the findings of Suresh kumar (2000) (4). Under drip irrigation, nutrient use efficiency was higher and fertilizer saving was around 30-50% (4, 5).

Soil nutrient dynamics under drip fertigation

The nutrients applied at each crop stage should be readily available in the soil to ensure their absorption without any hindrance. Leaching of nutrients, volatilization of fertilizers and fixation of nutrients in the soil are some of the factors that affect the availability of nutrients in the soil. The mobility of nutrients in the soil depends on the source of fertilizers, the levels of applied fertilizers and the ionic forms of the nutrient. Soil moisture also significantly influences the availability of N, P and K in the soil. The mobility of the applied nutrients can be assessed from soil samples taken at various distances from the emitter, both horizontally (0 to 25 cm) and vertically (0-15 and 15-30 cm) at 60 DAT for mapping. The mobility of nutrients in the soil depends on the source of fertilizer, application dose, forms of nutrient ions, soil moisture and other reactive ions present in soil solution.

Nitrogen dynamics

Irrespective of soil depth analysed for nutrients, more available nitrogen was accumulated in periphery regions of wetting zone. Among the fertigation treatments, peak available N was recorded in 100% N, P and K through fertigation (T_3) (253.8 kg ha^{-1}) at a distance of 25 cm away from emitter and a depth 15-30 cm soil layer. The same trend in terms of magnitude similarity was observed in other fertigation treatments also. Being mobile nutrient in soil, higher amount of nitrogen was accumulated in the periphery region of wetted zone. The mobility of available nitrogen as influenced by drip fertigation for 2 years study is depicted in Table 3 and Fig 1. In the present investigation, more nitrogen was accumulated in the periphery region of wetted zone of soil layer 15-30 cm below the emitter. This was due to movement of nitrogen in soil solution which led to more accumulation of available nitrogen in lower layer than surface layer of soil. Under drip irrigation, high soil moisture beneath the dripper increases the availability of nitrogen in the soil (4). Similar finding was noticed as higher NO_3-N concentration was found mostly in 15-30 cm soil layer (5). Nitrogen mobility in the soil occurred due to the concentration gradient, causing nutrients to move from higher concentration to lower one. The available soil moisture in the root zone plays a vital role in the mobility of nutrients (6). The study observed that higher soil moisture below the emitter corresponded to an increase in available nitrogen. A direct relationship was found between nitrogen availability and

Table 3. Nutrient dynamics under drip fertigation in onion (Pooled data).

Nutrient (kg/ha)	Soil depth (cm)	75% of 75% RDF			75% RDF			100% RDF		
		25 cm	Emitter	25 cm	25 cm	Emitter	25 cm	25 cm	Emitter	25 cm
Nitrogen	0-15	224.5	211.5	221.5	236.5	230.8	232.5	248.6	245.5	249.5
	15-30	230.8	220.5	228.6	248.7	245.5	249.5	253.8	250.4	254.2
Phosphorus	0-15	17.8	19.4	18.1	19.6	21.8	19.1	21.5	22.5	20.9
	15-30	15.8	17.5	15.2	17.4	18.4	17.8	18.4	21.1	18.2
Potassium	0-15	400.2	412.2	398.5	420.5	431.5	419.5	432.5	438.7	431.5
	15-30	394.7	401.5	392.5	415.2	421.5	412.5	427.5	431.5	424.6

RDF- recommended dose of fertilizer; *Data not statistically analysed.

soil moisture. The nitrate ion as being highly mobile in nature, it has a tendency to move away from the emitter to the periphery of the waterfront (7, 8).

Phosphorus dynamics

The mobility of phosphorus as average of 2 experiments as influenced by drip fertigation is depicted in Table 3 and Fig. 1. The higher available P in soil was confined to top layer 0-15 cm just below the emitter and decreased thereafter under all fertigation levels. The available P was higher in drip fertigation with 100% N, P and K through fertigation (T_3) (22.5 kg ha^{-1}) than other fertigation treatments. Generally, phosphorus was immobile in soil, soil applied Pas water soluble form resulted in increased mobility of P to some distance. Among the different nutrients required by onion crop, phosphorus is one of the highly demanded nutrients for higher yield (9). The higher quantity of available P was observed right below the emitter and thereafter decreased both vertically and horizontally in the present study. These results are in agreement with another findings (10). It was also found from the present investigation that higher availability of phosphorus was confined to 0-15 cm of soil layer. The available P decreased with increase in horizontal distance away from emitter. Similar finding was also reported earlier (6). The restricted mobility of phosphorus in soil might be attributed to its strong reactivity, as reported earlier (11). Subsequently, frequent fertilizer applications in smaller splits within the root zone increased phosphorus availability under drip fertigation (12). Further, study (13) supported the hypothesis that continuous application of P through drip irrigation system increased P availability when compared other application methods.

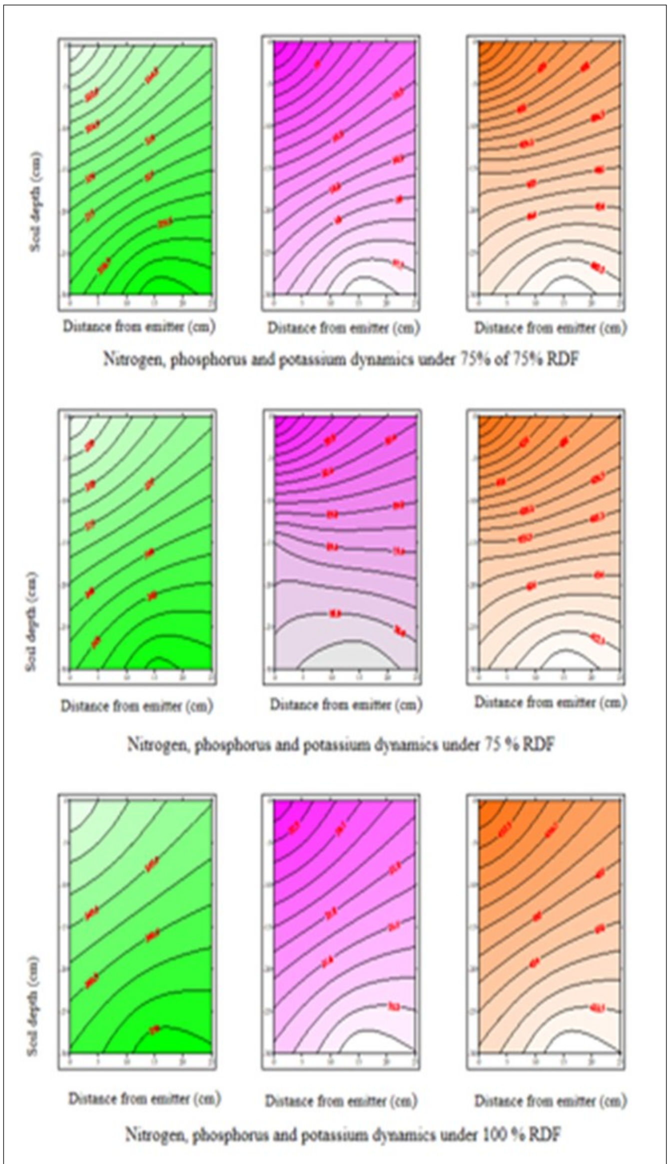

Fig. 1. Nutrient dynamics under drip fertigation.

Potassium dynamics

The mobility of potassium influenced by drip fertigation, averaged over 2 experiments, is depicted in Table 3 and Fig. 1. The potassium availability was higher in the top layers. The availability of potassium varied with soil layers and distance from the emitter point. Higher potassium availability was recorded just below the emitter (0-15 cm depth). Potassium availability was more under 100% N, P and K through fertigation (T_3) (438.7 kg ha^{-1}) than 75% RDF at 0-15 cm depth of soil layer in the emitter point. Available potassium was decreased with increasing depth from the emitter with irrespective of the distances. Potassium is less mobile in nature than nitrate but distributed uniformly in the wetted soil volume through interactions soil particles (14). In the present study, potassium mobility varied under and across the emitter under drip fertigation, as the highest available potassium was found in soil depth of 0-15 cm. This result was in line with another findings (15). Due to slow downward movement of potassium might be partially attributed to net upward flux of water in soil. This corroborates the findings of Zeng and Brown (2000) (16). Similar finding was also reported earlier (17, 18), who observed that potassium distribution in the soil profile is characterized by decreasing potassium content with increasing soil depth, with higher potassium content noticed at the 0-15 cm soil profile. This was mainly due to slow movement of surface applied potassium in soil. Additionally, it was also reported that the available potassium was higher in the surface layer due to entrance of potassium ions on soil exchange complex resulted in slow movement to deep soil layers (19).

Water use efficiency and Water Productivity in onion

The water use efficiency (WUE) and water productivity of onion were highly influenced by drip fertigation during both years due to the application of fertilizers at different levels as fertigation (Table 4). WUE was higher in 100% N, P and K applied through venturi as fertigation (T_3) (78.44 and 75.08 kg/ha mm) and was followed by 75% N, P and K through fertigation (T_7) (76.72 and 73.48 kg /ha mm). Conspicuously lower water use efficiency was registered in 75% N through fertigation with 75% P and K applied as basal (T_5) (58.05 and 55.57 kg/ha mm). Application of 100% N, P and K through fertigation (T_3) registered substantially higher water productivity (7.841 and 7.508 kg m^{-3}) which was followed by 75% N, P and K through fertigation (T_7) (7.670 and 7.348 kg/m^3). Barring absolute control, 75% N through venturi as fertigation with basal application of 75% P and K (T_5) (5.803 and 5.557 kg m^{-3}) registered perceptively lower and comparable water productivity. Consumptive use of irrigation water calculated by adding the amount of irrigation water required to meet the demand of evapotranspiration and effective rainfall during the crop growing season. The data pertaining to water use indicated that a significantly higher WUE and water productivity were registered in 100% N, P and K through fertigation (T_3) and 75% N, P and K through fertigation (T_7). This might due higher

Table 4. Influence of drip fertigation on water use, Water Use Efficiency (WUE) and Water Productivity (WP) of onion.

Treatment	First experiment			Second experiment		
	*Total water use (mm)	WUE (kg /ha mm)	WP (kg /m³)	*Total water use (mm)	WUE (kg /ha mm)	WP (kg m⁻³)
T_1- 100% N through fertigation with 100% P and K applied as basal	296.4	61.08	6.106	312.6	58.48	5.848
T_2- 100% N and K through fertigation with 100% P applied as basal	296.4	67.54	6.752	312.6	64.65	6.465
T_3- 100% N, P and K through fertigation	296.4	78.44	7.841	312.6	75.08	7.508
T_4- 75% N, P and K through fertigation and 25% N, P and K applied as basal	296.4	69.59	6.957	312.6	66.63	6.663
T_5- 75% N through fertigation with 75% P and K applied as basal	296.4	58.05	5.803	312.6	55.57	5.557
T_6- 75% N and K through fertigation with 75% P applied as basal	296.4	64.77	6.475	312.6	62.00	6.200
T_7- 75% N, P and K through fertigation	296.4	76.72	7.670	312.6	73.48	7.348
T_8- 75% of 75 % N, P and K through fertigation and 25% of 75% N, P and K applied as basal	296.4	68.70	6.868	312.6	65.77	6.577
T_9- 50% N and 100% P, K applied as basal and 50% N applied on 30 DAT	296.4	59.87	5.985	312.6	57.33	5.733
T_{10}- Absolute control	296.4	46.96	4.695	312.6	44.95	4.495

Total water use includes effective rainfall also; *data not statistically analysed.

yield (Fig. 1) and frequent application of irrigation water through drip irrigation system, which helped in maintaining the soil moisture of crop root zone near field capacity and reduced the movement of water beyond root zone. Similar findings were also reported, indicating higher water use efficiency (WUE) for daily and alternate-day drip irrigation (20, 21).

Effect of drip fertigation on bulb yield of onion

Application of nutrients through drip fertigation significantly influenced the bulb yield and the data are presented for 2 years in Table 5. The highest bulb yield was noticed in 100% N, P and K through fertigation (T_3) (23.24 and 23.47 t ha^{-1}) and it was comparable with 75 % N, P and K through fertigation (T_7) (22.74 and 22.97 t ha^{-1}). Moderate yields were recorded in 75% N, P and K through fertigation and 25% N, P and K applied as basal (T_4) (20.62 and 20.83 t ha^{-1}) and was comparable with 75% N, P and K through fertigation (T_7). The increase in yield might be due to higher number of bulbs, bulb weight due to increase in the availability of all the major nutrients (NPK) in the soil solution which in turn increased the uptake of nutrients and effective translocation of assimilates from source to sink led to higher crop yield. This was in line with the findings of a previous study which stated that application of 100% WSF as fertigation increased the fruit yield significantly over drip irrigation with soil application of nutrients (22). Similarly, another study also reported higher onion yield in both daily and alternate day fertigation (21). Application of 75% N through venturi as fertigation and basal application of 75% P and K (T_5) (17.20 and 17.37 t ha^{-1}), 50% N, 100% P and K applied as basal and 50% N applied on 30 DAT (T_9) (17.74 and 17.92 t ha^{-1}), 100% N through fertigation with basal application of 100% P and K (T_1) (18.10 and 18.28 t ha^{-1}) and 75% N and K through fertigation with basal application of 75% P (T_6) (19.19 and 19.38 t ha^{-1}) registered significantly lower and comparable yield. The substantially lower yield observed in 75% N through fertigation with 75% P and K applied as basal (T_5) might be attributed to lower nutrient absorption efficiency of granular fertilizer. When applied through broadcasting these fertilizers are prone to leaching and volatilization losses, leading to reduced availability of plant uptake. This is consistent with the findings of a previous study (23).

Conclusion

The conclusion drawn out from the above investigation are as follows: Drip fertigation with 100% N, P and K through venturi recorded substantially higher nutrient use efficiency, which was comparable with 75% N, P and K through fertigation. Irrespective of depth significantly higher amount of available N accumulated near the periphery region of the wetting zone. For P and K, higher concentrations were observed directly below the emitter. Application of 100% N, P and K through venturi as fertigation and 75% N, P and K through fertigation recorded higher water use efficiency (78.44 kg/ha mm) and water

Table 5. Yield attributes and yield of onion as influenced by drip fertigation treatments.

Treatment	First experiment	Second experiment
	Bulb yield (t ha⁻¹)	Bulb yield (t ha⁻¹)
T_1- 100% N through fertigation with 100% P and K applied as basal	18.10	18.28
T_2- 100% N and K through fertigation with 100% P applied as basal	20.01	20.21
T_3- 100% N, P and K through fertigation	23.24	23.47
T_4- 75% N, P and K through fertigation and 25% N, P and K applied as basal	20.62	20.83
T_5- 75% N through fertigation with 75% P and K applied as basal	17.20	17.37
T_6- 75% N and K through fertigation with 75% P applied as basal	19.19	19.38
T_7- 75% N, P and K through fertigation	22.74	22.97
T_8- 75% of 75% N, P and K through fertigation and 25% of 75% N, P and K applied as basal	20.36	20.56
T_9- 50% N and 100% P, K applied as basal and 50% N applied on 30 DAT	17.74	17.92
T_{10}- Absolute control	13.91	14.05
SEd	**1.05**	**1.06**
CD (P=0.05)	**2.21**	**2.23**

productivity (7.841 kg m^{-3}). Onion bulb yield was higher in 100% N, P and K through fertigation (23.24 t ha^{-1}). In aggregatum onion cultivation, application of 75% N, P and K through fertigation using water soluble fertilizers in weekly intervals was identified as the optimal fertigation treatment to achieve higher nutrient use efficiency, nutrient dynamics, water use efficiency, water productivity and bulb yield. These results offer a highly efficient, eco-friendly alternative to traditional irrigation and fertilizer application in onion cultivation.

Acknowledgements

Authors acknowledge ICAR-AICRP for providing financial support for this work.

Authors' contributions

SKN, JB conceived idea, planned the work and carried out the experiments and statistical analysis. TS, MM and ST drafted the manuscript and corrected. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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